Human Reliability Analysis Methods for Space Safety

RMC, Session G: Human Error and Risk Assessment

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Human Reliability Analysis (HRA)

Definition

- *The use of systems engineering and behavioral science methods in order to render a complete description of the human contribution to risk and to identify ways to reduce that risk*

Scope of Talk

- *Review current HRA methods*
- *Apply these HRA methods to NASA*

Snapshot of Current HRA Methods

Some Popular Methods (Out of 50+ Contenders)

- *THERP (Swain & Guttman, 1983)*
  - *Technique for Human Error Rate Prediction*
- *CREAM (Hollnagel, 1998)*
  - *Cognitive Reliability and Error Analysis Method*
- *ATHEANA (NRC, 2000)*
  - *A Technique for Human Event ANAlysis*
- *SPAR-H (Gertman et al., 2005)*
  - *Standardized Plant Analysis Risk-Human Reliability Analysis*

Advantages of Methods

- *All methods have successfully accounted for contribution of human performance to overall risk and reliability*
- *All methods allow quantification of human error probability*
- *All methods have been applied extensively to nuclear power plants, and some to the space domain*

Differentiating HRA Methods

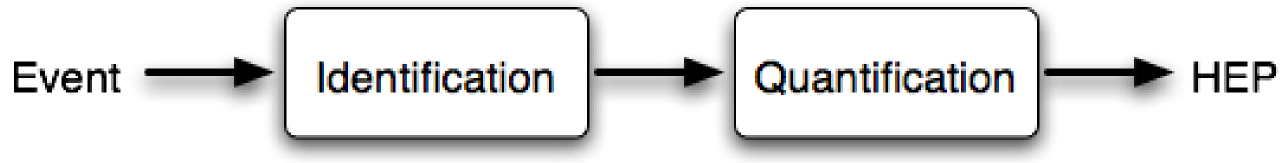
With 50+ HRA methods to choose from, how do you decide the best one for NASA applications?

- *Current HRA methods are different on a number of dimensions*
  - *Qualitative v. Quantitative HRA Methods*
  - *First v. Second Generation HRA Methods*
  - *Holistic v. Analytic HRA Methods*
  - *Few v. Many Performance Shaping Factors in HRA*

Qualitative v. Quantitative HRA

Qualitative HRA

- *Focused on identification of the event or error*
- *Common result of task analysis or incident investigation*



Quantitative HRA

- *Focused on translating identified event or error into a Human Error Probability (HEP)*

Qualitative and quantitative are complementary

- *Not all events are well enough understood to be quantified*

Quantitative HRA Methods

Expert Estimation

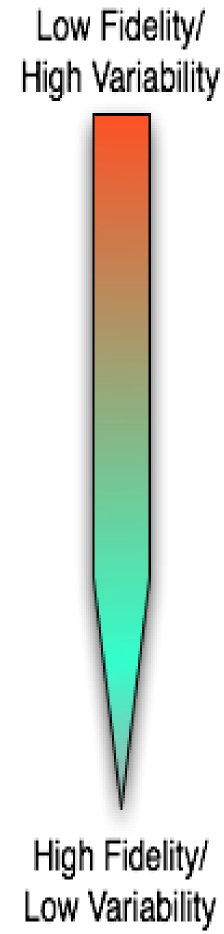
- *Determination of an HEP based on expert knowledge of the likelihood that a person would falter in a given context*

Performance Shaping Factors (PSFs)

- *Use of factors known to degrade or improve human performance over an established baseline*
- *PSFs often treated as multipliers on a nominal HEP*

Frequency Based Estimation

- *Use of performance data derived from observation of similar events or contexts*
- *Error is the number of observed failures divided by the number of observed trials in which the human performed the task*



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First v. Second Generation Methods

First Generation HRA Methods

- *Use a simple error taxonomy*
- *Use a simple "fits"/"doesn't fit" dichotomy to match error scenario to error identification and quantification*

Second Generation HRA Methods

- *Use a theory-based error taxonomy*
  - *Often coincides with cognitive model of human behavior*
- *Use a complex match of error scenarios to error identification and quantification*
  - *PSFs with multiple levels of assignment to indicate degrees of degraded or enhance performance relative to nominal*

Holistic v. Analytic Methods

Holistic HRA Methods

- *View human performance as indivisible part of whole situation that cannot be broken into smaller parts*
- *Analyze event without having fixed list of root cause contributors*

Analytic HRA Methods

- *View human performance as a composite of its individual elements of human performance*
- *These elements may be decomposed and analyzed individually*
- *Analyze an event or error using rubric of root cause contributors*

Judgment Strategy

Cause of Incident	Atomistic	Holistic
Univariate	*Works well if one of the items on rubric/ checklist matches the cause of the event.*	*Works well if analyst avoids extraneous factors.*
Multivariate	*Rubric/checklist helps analyst focus on relevant contributors to multivariate events.*	*Prone to inclusion of extraneous factors or scaling biases for multivariate events.*

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Few v. Many PSFs in HRA Methods

Few PSFs

- *Focus on high-level PSFs that encompass many categories of performance contribution*
  - *environment | organization | individual (Galyean, 2006)*

Many PSFs

- *Attempt to provide comprehensive model of contributors to human performance*
  - *From 8 PSFs in SPAR-H to ~50 in IDAC*
- *PSFs may not always be orthogonal, but methods may attempt to control for double-counting of related influences*
- *Not all PSFs count for every event or error*

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Meaningful Distinctions

HRA Methods were developed for different purposes

- *Distinctions between HRA methods reflect the usage requirements for different HRA applications*
- *To the extent that space safety meets these intended uses, these methods may be effectively used in NASA*

		Qualitative		Quantitative	
		Few PSFs	Many PSFs	Few PSFs	Many PSFs
First Generation	Holistic				
	Analytic				
Second Generation	Holistic				
	Analytic				

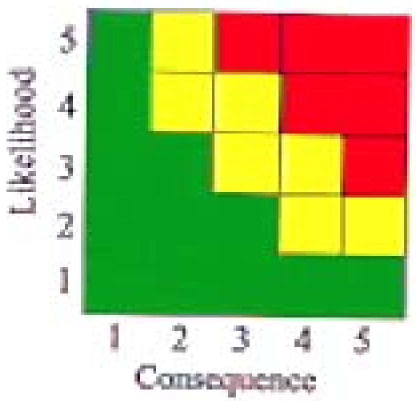
Limitations

- *No HRA method designed specifically for NASA domains*
- *No HRA method baselined to human performance data from NASA domains*
  - *Beyond ground processing and control, spacefilight domains do not closely overlap nuclear power plants from which most HRA quantification is derived*

Path Forward for HRA in Space Safety

Qualitative HRA Methods for NASA

- *NASA mishap investigations identify current and historical sources which may have human contributors*
- *Human Factors Process Failure Modes and Effects Analysis (HF PFMEA)*



- *Root cause analysis*
- *Task analysis*

Path Forward for HRA in Space Safety

Quantifying HRA for NASA

- *Research literature*
  - *Extensive available literature on human performance in extreme environments*
  - *Match applicable domains (e.g., underwater diving) to determine probable performance in space*
- *NASA operating history*
  - *Extensive logging of events through simulators can provide indication of situations that may challenge human to perform optimally*
- *Determination of space specific PSFs*
  - *Bioastronautics Roadmap*

Quantification information is being compiled in HRA database created by INL for NASA

- *Goal: Allow future HRA quantification efforts at NASA to be informed by most relevant space data sources*

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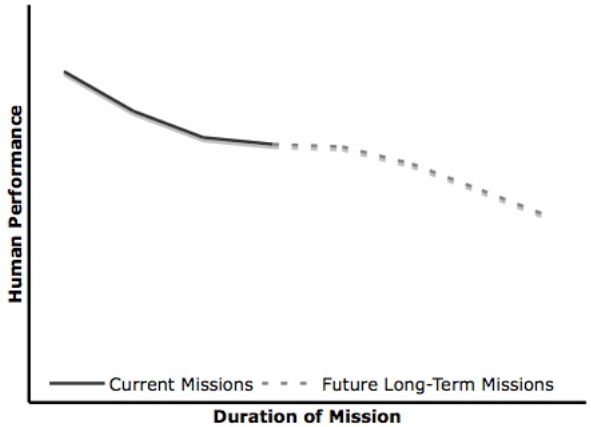
Path Forward for HRA in Space Safety

Quantification through Simulation: “Third Generation” HRA?

- *Use of modeling and simulation system with virtual representation of humans to determine situations that may challenge human performance in space missions*
- *Process*
  - *System extensively calibrated to human performance in known situations*
  - *Across many Monte Carlo style trials, performance extrapolated to novel situation (e.g., long-duration space flight) for which actual human performance data have not been collected*



  - *Provides preliminary estimates of human error as well as “red flags” for situations that need to be further investigated to determine actual risk to humans or risk of human error*

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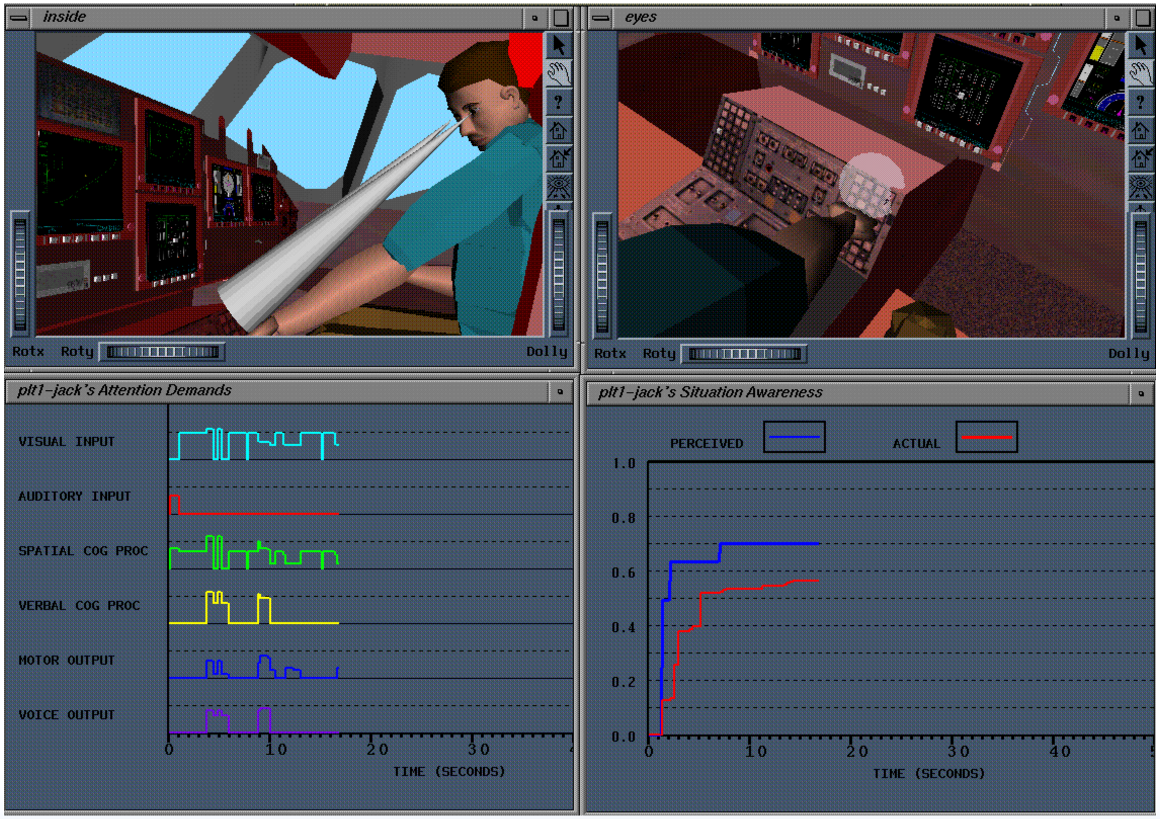
Path Forward for HRA in Space Safety

Quantification through Simulation: “Third Generation” HRA?

- *Example NASA simulation architecture: MIDAS*



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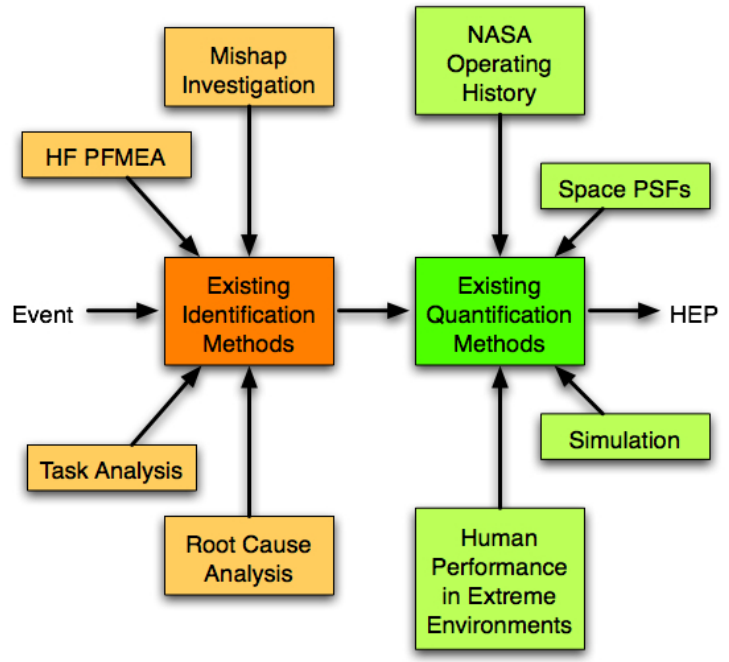
An HRA Method for Space Safety

Existing HRA methods may produce error estimates that don't fully reflect what is known about human performance in space domains

- *Augmenting NASA tools and methods to existing HRA methods increases the ease and fidelity of making HRA estimates for space safety*



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